EROSIVE WEAR BEHAVIOR OF POMEGRANATE PEEL REINFORCED EPOXY COMPOSITE

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In

Mechanical Engineering

By

KAUSAR SHAMIM

(111ME0347)

Under The Guidance Of

Prof. S.K ACHARYA

Department Of Mechanical Engineering

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DEPARTMENT OF MECHANICAL ENGINEERING
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ORISSA, INDIA-769008

CERTIFICATE

This is to certify that the thesis entitled **"EROSIVE WEAR BEHAVIOUR OF POMEGRANATE PEEL REINFORCED EPOXY COMPOSITES"** submitted by **Mr. KAUSAR SHAMIM** in partial fulfilment of the requirements for the award of **Bachelors of Technology Degree in Mechanical Engineering** at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge the matter embodied in the thesis has not been submitted to any other university/Institute for the award of any degree or diploma.

Place: Rourkela
Date: 6th June, 2015

Prof. S. K. ACHARYA
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ACKNOWLEDGEMENT

I am obliged to express my thankfulness and commitment to my project supervisor **Prof. S. K. Acharya** for his advices, guidelines, constructive criticism, and support which helped me continue with my work.

I also show my gratefulness to the Director of National Institute of Technology, Rourkela, **Prof. Sunil Kumar Sarangi** and to the Head of the Mechanical Engineering Department, **Prof. S.S. Mahapatra** and all staff members of the Mechanical department.

I am also thankful to **Mrs. Niharika Mohanta, Mrs. Shakuntala Ojha, Ms. Soma Dalbehera and Ms. Tanushree Bera** who spent their valuable time in assisting me with the project work. I express my sincere thanks to **Mr. Prajapati Nayak, Mr. Rama Prasannaa Pradhan** and **Mr. Gaurav Kumar Garg for** their support & help during my experimental work.

Moreover, I show my extreme gratitude to my father **Mr. Mohammad Ehsan Ansari**, mother **Mrs. Yasmin Khatoon** and my friends for their moral encouragement, support and advices for the successful completion of the project.

Kausar Shamim

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ABSTRACT

Over many years, polymers have emerged as a standout amongst the most key components in our daily life. One such polymer which is very common is Epoxy resins. Nowadays, natural filler and fiber materials have taken over synthetic filler materials as reinforcement in polymer materials such as Epoxy to improve its durability and toughness. These filler materials are environment friendly, present abundantly, renewable and cost effective because of which they find their place in most of today's composite materials.

The fibers and their weight percentages are to be considered during the preparation of the composite materials. Previously, many research efforts have been put to study the effectiveness of natural fibers on the erosive wear behavior of epoxy composites.

The present study is done to know about the erosive wear behavior of pomegranate peel reinforced epoxy composites. The composites were prepared with 5%, 10%, 15%, 20% weight percent fraction of pomegranate peel by using Hand Lay-up technique. The cutting of the composite materials was done according to the ASTM standards for different experiments. The samples were ten tested for their erosive wear properties at three different velocities i.e. 48 m/s, 70 m/s and 82 m/s obtained at 1 bar, 2 bar and 3 bar pressures respectively.

CHAPTER 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1 Background and Motivation-

Today, the researchers over the world are persuaded to study natural fiber reinforced polymer composite along with synthetic fiber reinforced composites. Availability of natural fibers and their ease of manufacturing have persuaded researchers to study low cost locally available fibers and to test their viability of reinforcement purposes and up to what extent the fibers fulfill the needed specifications of good reinforced polymer composites for diverse purposes. Also, natural fibers represent a fine renewable and biodegradable substitute for glass fiber which is the most common synthetic reinforcement due to its low cost and high specific mechanical properties.

"Natural fibers" covers a broad range of vegetable, animal and mineral fibers. These fibers greatly influences the structural performance of plants and, when utilized as a part of plastic composites, can give huge support. In composite industries, natural fibers are usually referred to as wood fiber and agro based bast, stem fibers and leaf seeds. Regardless of the interest and natural appeal of normal fibers, there utilization is restricted to non-bearing applications because of their lower strength compared with synthetic fiber reinforced polymer composite. The strength and stiffness deficiencies of bio composites can be overcome by structural configurations and better arrangement of fibers i.e. placing them in specific locations for highest strength performance. Broad studies on preparation and properties of polymer matrix composite (PMC) supplanting the synthetic fiber with natural fiber like Sisal, bamboo, Kenaf, Bagasse, Jute and Pineapple were completed [1-6]. These plant fibers have numerous benefits over glass fiber or carbon fiber like renewable, low cost, eco-friendliness, lightweight, high specific mechanical performance. Thermoplastic polymers which are high performance synthetic filler materials have been utilized over the past few decades [7] to be used filler materials because of their better toughness and thermal stability. Notwithstanding, recently there has been revival in endeavours towards finding out environment friendly solutions which would increase the production of natural filler materials [7]. They are non-toxic and biodegradable [8]. They can be worked upon naturally to develop rigidity and strength like their synthetic replacements. They are an abundant asset, intensely accessible, renewable, and can help in financially savvy production. Some demerits of natural filler materials are reduced effectiveness with hydrophobic polymers due to moisture sensitivity [9], biological decay, non-uniformity in shapes and sizes of filler, weakness to natural environmental attacks, and lack of hardiness under higher temperatures [10]. Nevertheless, natural filler materials can be post processed in order to lessen some of the above demerits, specifically, degradation under moisture and some environmental impacts [9]. Low density, excellent stiffness and good mechanical and thermal properties are some of the features of composite materials. This is why they find a good place in automotive, construction and packaging applications.

Bio composite is a material produced by a matrix and a reinforcement of a plant derived fiber. It is required to develop novel bio based items and other creative technologies that can decrease reliance on fossil energizes. Eco-friendly bio composites from plant inferred fibre and crop-derived plastics make an extraordinary significance to nature and are likewise an answer for the instability of petroleum supply.

Natural/bio fibers can be comprehensively divided into two classes: non-wood fibers and wood fibers indicated in the Figure 1.1. At present level of innovation non wood fibers like hemp, kenaf, flax and sisal discover business achievement in the configuration of bio-composites from polypropylene for automotive applications.

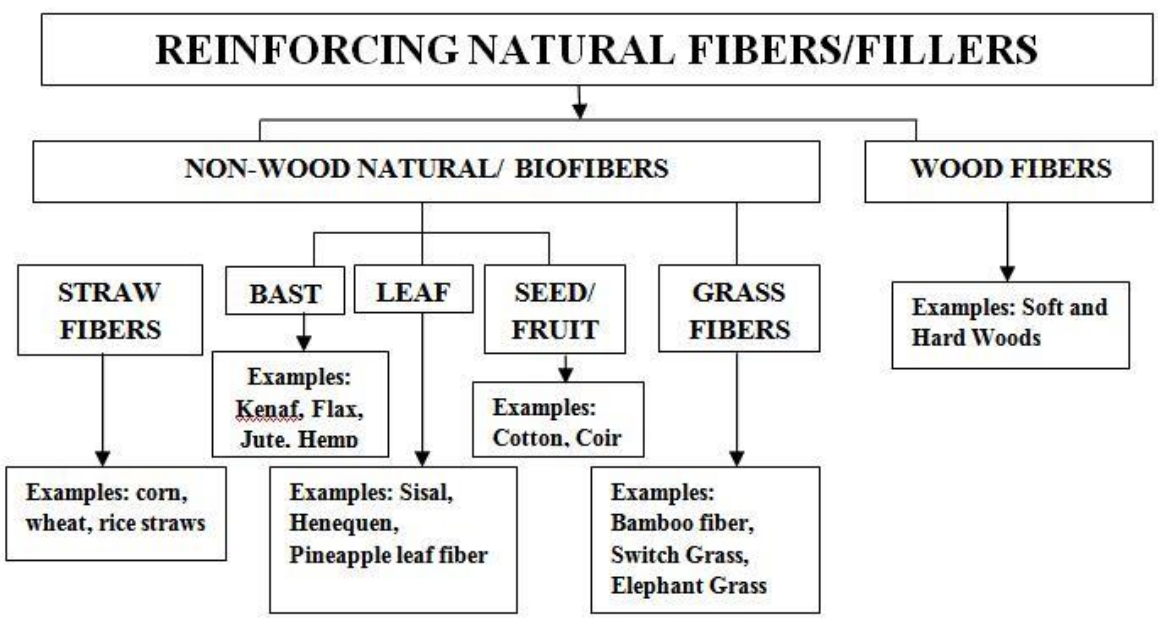

Figure 1.1 Classifications of Natural Fibers

Natural fiber composites are useful for the following applications-

- Storage devices like bio gas containers, grain storage silos and post boxes.
- Furniture like chair, table, bath units, sofas, etc.
- Electrical devices like electrical appliances.
- Everyday applications like Lampshades, suitcases, helmets, etc.
- Transportation purposes like automobile, boats, aircraft interiors and outer body, etc.
- Toys for children.

Composite materials are better than many conventional materials like metals because of their low density, excellent stiffness and amazing mechanical and thermal properties. Different types of polymer show differnent tribological and mechanical behaviour. Nevertheless, neat polymers is very seldom used as bearing materials and wear resistance materials because of the fact that unmodified polymer could not fulfil the demands arising from the circumstances in which a combination of good mechanical and tribological properties is required [11]. However according to the data of the investigator there is no data accessible on the mechanical conduct of fruit waste. Some work has been done by Abdul Khalil et.al [12] to describe the epoxy composite reinforced with bio-based filler materials like coconut shells, bamboo stems and oil palm fiber bunches. Their results confirmed that there was enhancement in thermal stability of the carbon black reinforced composite when compared to the neat epoxy.

1.2 Thesis Outline -

The remaining part of the thesis is organized as follows-

Chapter 2 - This chapter portrays the previous work done related to the present study available in literatures.

Chapter 3- This chapter displays the details of materials needed, density measurement of filler and composite manufacturing procedures.

Chapter 4- In this section, the details of the erosion test apparatus, steps taken to perform the test, formula for erosion rate calculation and experimental results are shown.

Chapter 5- In this section, the results and discussions of the above test is displayed.

Chapter 6- In this section, the conclusions and scope for future work are depicted.

CHAPTER 2

LITERATURE SURVEY

CHAPTER 2

LITERATURE SURVEY

2.1 Literature Survey

Literature survey is carried out to get the background information on issues to be considered in the present research study. The objective of Literature survey is also to present an intensive understanding of various features of bio polymer composite with special emphasis on their erosive wear properties. The fibers can be either synthetic fibers or natural fibers in fiber reinforced polymer composites. Natural fibers constituents are primarily of cellulose fibers which comprising of helically twisted cellulose micro fibrils, held together by an amorphous lignin matrix. Lignin basically keeps water in fibers. So, the fibers are well protected from any biological attacks and this also gives the stem its resistance to wind and gravity forces. Hemicellulose in the natural fibers acts as a compatibilizer in between lignin and cellulose [13].The use of lignocellulosic fibers as reinforcements for polymeric materials has been developing during previous decades to supplant synthetic fibers, particularly glass fibers in composites, for packaging, automobiles and various applications in industrial sector [14,15]. Apart from this, it is also used in building sector [16]. This is chiefly due of their novel qualities like accessibility, biodegradability, low density, non-toxic nature, less abrasiveness to plastic processing equipment, useful mechanical properties and low cost [17]. The physical mechanical properties of natural fibers are enormously influenced by their chemical compositions.

All natural fibers can be classified based on its origin and regarding the plant-based fibers, they are further classified according to the part of the plant they are recovered from. The classification of natural fibers is shown in the following figure (Fig-2.1).

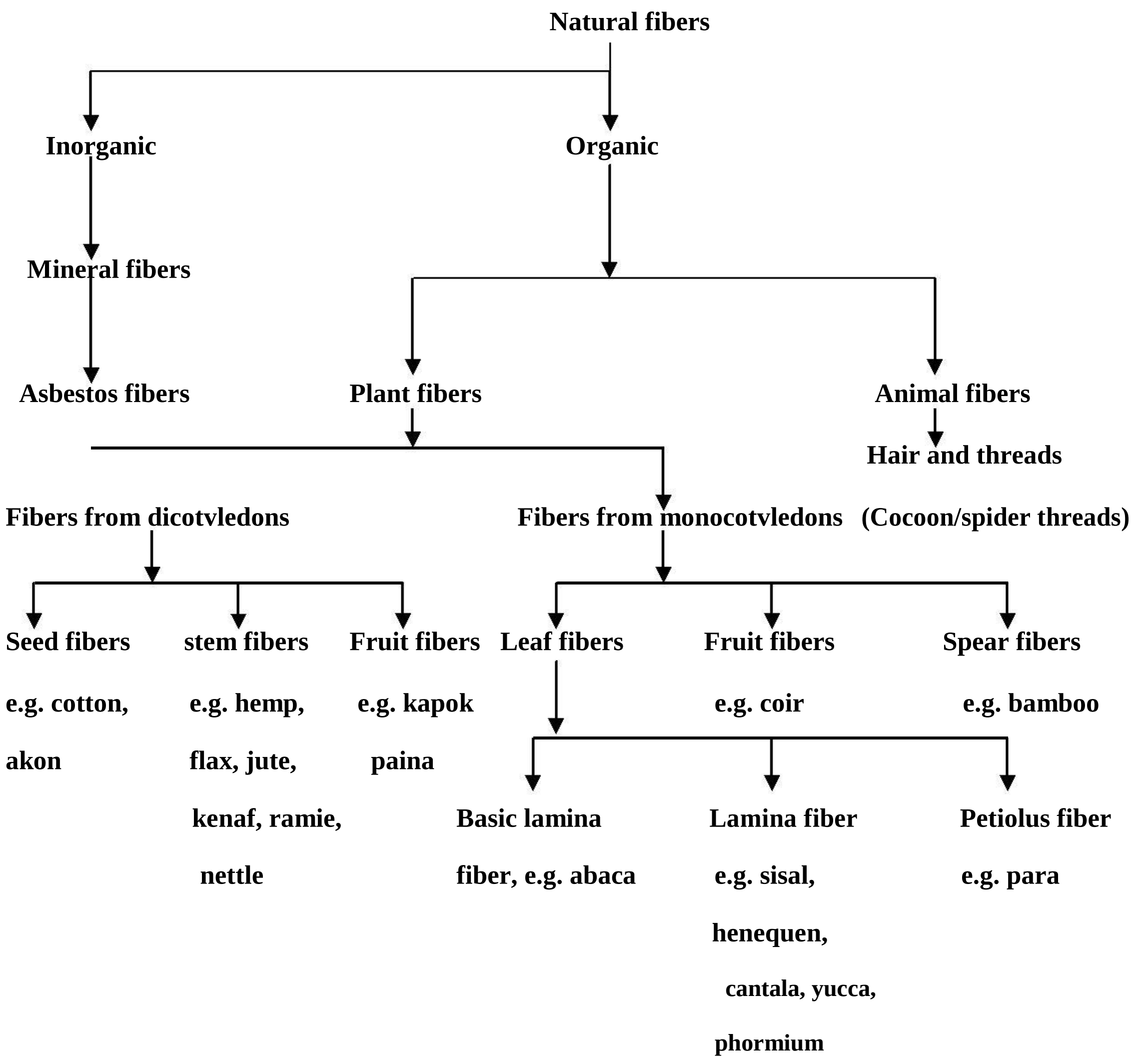

Figure 2.1 Overview of Natural fibers

The Epoxy resins (ER) belongs to thermosetting polymers. The ER is extensively used as matrices for fiber-reinforced composite materials and as structural adhesives[18-23]. ER has got merits and demerits of its own. The merits include amorphousness, high cross-linked polymers resulting in high tensile strength and modulus, simple processing, fine chemical and thermal resistance and dimensional stability [18]. Its demerits include low toughness and poor resistance to cracks. However, by incorporating a second phase of dispersed rubbery particles into the polymer, the toughness of the epoxy resin can be made better [24-26].

Ahmed et al. [27] did research work on filament wound cotton fiber reinforced for reinforcing high density polyethylene (HDPE) pitch. Khalid et al. [28] likewise considered the utilization of cotton fiber reinforced epoxy composites alongside glass fiber reinforced polymers. Fuad et al. [29] researched the new sort wood-based filler got from oil palm wood flour (OPWF) for bio-based thermoplastics composites by thermo gravimetric investigation and the outcomes are extremely encouraging.

Schneider and Karmaker [30] created composites utilizing jute and kenaf fiber and polypropylene resins and they reported that jute fiber gives preferred mechanical properties over kenaf fiber. Amid leaf defibration of henequen fiber and furthermore amid the change of the raw fibers into cordage, pretty nearly 10% of waste fibers are created. These waste filaments could be beneficially utilized as a part of the production of fiber polymer reinforced composites on the grounds that they possess alluring physical and mechanical properties [31].

2.2 Summary of previous work done-

The following facts are revealed by the above literature survey-

- Ample amount of work has been done on various natural fibers consolidating with polymer matrices, bringing about enhancement in erosive wear properties of the composites compared with the matrix material.
- The main demerit of natural fiber reinforced composites is their property to soak up dampness. For that reason, number of researches has been done to comprehend and enhance this nature of natural fiber reinforced composites.

2.3 Objectives of the Present Work-

The objectives of the present work are-

- Preparation of Pomegranate peel particulates of required particle size.
- Calculation of density of Pomegranate peel powder using Pycnometer.
- Fabrication of composite with different weight percentage of particulate filled epoxy matrix.
- Performance of erosive wear tests on the composite samples.

CHAPTER 3

MECHANIAL CHARACTERIZATION

CHAPTER 3

MECHANICAL CHARACTERIZATION

3.1 Materials and Method

For the project, the raw materials that were used are-

- Natural filler (Pomegranate Peel powder)
- Epoxy resin
- Hardener

3.1.1 Pomegranate Peel-

The pomegranate is believed to have originated in the region extending from Iran to northern India. At present, it is widely grown and cultivated all over the Middle East countries and in the Caucasus region. Northern and tropical Africa, the Indian subcontinent, Central Asia and arid parts of southeast Asia are also involved in its cultivation. Its pH value ranges from 2.93-3.20. Thus, it is an acidic fruit.

(a) Pomegranate peel (b) Dried Pomegranate peel (c) Pomegranate peel powder

Fig 3.1 Different phases of Pomegranate peel

The pomegranate peel is uneatable. When compared to the pulp of this fruit, the peel contains as much as three times the total quantity of polyphenols, including condensed tannins and catechins, gallocatechins and prodelphinidins.

Oven was used to heat the finely grinded Pomegranate peel to remove every trace of moisture from it.

3.1.2 Epoxy Resin-

The type of epoxy resin that was used in the investigation was LY556 (Araldite) which chemically belongs to the epoxide family. Its common name is Bisphinol-A-Diglycidyl-Ether.
It has been utilized as the matrix material because if its excellent properties-

- Excellent adhesion to different materials.
- Great strength and toughness resistance.
- Excellent resistance to chemical attacks and to moisture.
- Excellent mechanical and electrical properties.
- Odourless, tasteless and non toxic.
- Shrinkage is negligible.

3.1.3 Hardener-

The hardener used in the present experiment was HY951, aliphatic Primary amines with IUPAC name NNO-bis (2aminoethylethane-1,2diamin) having viscosity of 10-20 MPa at 25°C.

3.2 Measurement of filler (Pomegranate Peel Powder) density

The density of the filler was found out by using Pycnometer.
The formula that had been used for the calculation of filler density in the experiment is,

Density of filler = ρ_r x density of kerosene

Where,

ρ_r represents the relative density of the filler material and is given by,

$$\rho_r = \frac{Wo}{Wo + (Wa - Wb)}$$

Where,

w_o is the weight of the sample (filler)

w_a is the weight of pycnometer bottle + weight of kerosene

w_b is the weight of pycnometer bottle + weight of kerosene + weight of sample

The density of kerosene for the above calculations was taken to be 0.817 g/cc.

3.3 Preparation of Composite

The composite was prepared by Hand Lay-up method. In this method, a wooden mold of area 140x60 mm^2 with thickness from 3mm to 5mm was utilized for preparation of the composite. Initially, a per-pex sheet was cut out and the dimensions were drawn on the sheet. After that, wooden sticks which would ultimately form the mold were fixed on the per-pex sheet over the previously drawn dimensions. One to three cardboards were cut out of the same size as that of the rectangle. In a similar way, glass sheet was cut out of the same dimension. All this was done for each of the composites to be prepared with different weight percentages of Pomegranate peel (i.e. 5%, 10%, 15% and 20%) mixed with the matrix material .The hardener was also added to the mixture of filler and matrix in the ratio 10:1 by weight. Silicon spray was sprayed on to the glass sheet and inner surfaces of the wooden mold so that the composite prepared doesn't attach itself firmly to the walls of the mold during its removal. The mixture of matrix, filler and hardener was then carefully poured into the mold. Care has to be taken during pouring to avoid any entrapment of air bubbles which decreases the stiffness and rigidity of the composites. So, slight stirring was done to ensure uniform thickness. The glass sheet was then placed on top of the mixture and the cut out cardboards were subsequently placed on its top. Weights were kept on top of this arrangement so as to apply pressure. This arrangement was kept undisturbed for 24 hours for the mixture to harden. Some extra material has to be taken to compensate for the loss of material as it squeezes out when pressure is applied. After the time has elapsed, the samples were taken out from the mold and the composite was cut into desired size for the erosive wear rate test. The required size of the sample was of 2.5x2.5 cm^2 square cross-sectional area.

Fig 3.2 Mold for preparing the composite

Fig 3.3 Prepared composite

CHAPTER 4

STUDY OF EROSIVE WEAR RATE

CHAPTER 4

STUDY OF EROSIVE WEAR RATE

4.1 Introduction

Solid particle erosion has been considered as a major problem because it has lead to many failures in engineering applications. This is because solid particle erosion results in thinning of parts, roughening of surfaces and their wearing away and leads to decline in the functional life of the components. There were many attempts made in the history to understand how erosion occurs between last half of the 20^{th} century and up to the present. In the year of 1995 an article on the past and the future of erosion was exhibited by Finnie [32]. In this article, the impacting parameters and ruling mechanisms amid solid particle erosion were assessed on the erosion reaction of metals and ceramics. Around the same time another article was presented by Meng et al. [33] to give data about the current wear models and expectation equations.

4.2 Definition

As per Bitter [34], erosion is a material degradation brought about by the attack of particles entrained in a fluid system affecting the surface with rapidness. Hutchings [35] characterizes it as a abrasive wear process in which the rehashed effect of little particles entrained in a moving liquid against a surface result in the expulsion of material from the surface. Erosion because of the effect of strong particles can either be helpful or damaging, and in this way, it can be needed to either minimize or augment erosion, according to the use. The helpful uses incorporate sand blasting, high velocity water-jet cutting, blast stripping of paint from planes and vehicles, impacting to expel the adhesive flash from bonded parts, erosive drilling of hard materials. Though the solid particle erosion is damaging in industrial applications, for example, erosion of machine parts, surface erosion of steam turbine blades, erosion of pipelines transporting slurries and particle erosion in fluidized bed combustion systems. In most erosion procedures, material removal commonly happens as the consequence of countless impacts of irregular particles, generally conveyed in pressurized liquid streams.

4.3 Solid Particle erosion of Polymer Composites

The issue of erosion wear of polymer composite has gotten considerable consideration in the previous decades. Concern for this subject is proportionate with the expanding usage of polymer based composites in aviation, transportation and processing industries. For example, applications like sand slurries transported in pipelines in petroleum refining, rotor blades of helicopter , blades of pump impeller, and airplanes working in desert environment, where the component experiences effect of many abrasives like dust, sand, chips of materials, slurry of strong particles and so the materials experience erosive wear.

Numerous researchers have studied the erosive wear resistance of different sorts of polymers like nylon, epoxy, polypropylene, bismileimide, and many more and their composites too.

Parameters affecting the erosive wear rate of composite materials are categorized broadly into the following categories-

- Properties of the material that has to undergo erosion (properties of the matrix, type of the reinforcement used, amount of reinforcement added in the matrix and in what orientation, properties of the interface between matrix and the reinforcement).
- Conditions where the erosion testing has to take place and that of the environment (temperature, chemical interactions between erodent and the composite material).
- Operating parameters (velocity of impingement, impingement angle, mass of particles per unit time i.e. particle flux).
- Erodent properties (shape, size, hardness, type of the erodent used)

So, it is obvious that in order to calculate the erosive wear rate of the material, the combination of all the above parameters has to be taken into consideration. The erosive behavior of the materials can be divided into two categories when the angle of impingement is taken into account: ductile and brittle. If maximum erosion rate occurs at an angle between (15°-30°), the material is ductile. If the maximum erosion rate occurs at an impingement angle between (60°-90°),then the material is brittle in nature. Polymer reinforced composites can also show intermediate behavior known as semi-ductile. This is when the maximum erosion occurs at an angle in the range of (30°-60°).

Knowing the importance of polymer composites, the researchers have conducted studies by taking a variety of thermoset and thermoplastic PMC's comprising of glass, graphite, carbon and Kevlar fibers as reinforcements. Also, there is no study made on the erosive wear rate of Pomegranate peel reinforced epoxy composites, so in this study, some attempt has been made to gain some information on resistance of the Pomegranate peel reinforced epoxy composite to erosion.

4.4 Experiment

4.4.1 Test specimen preparation

Chapter 3 already portrays the method of preparation of the samples. The samples required for the erosion test need to be of some specific dimension. In this study, test samples of size 25x25 mm^2 area was cut with the thickness ranging between (3–5)mm. The samples were cut from the composite by a hack saw.

4.4.2 Test apparatus

Fig 4.1 shows the test apparatus employed for the erosion test. The erosion test apparatus is designed according to the ASTM-G76 standards. Magnum engineers, Bangalore designed and manufactured it. The equipment is aesthetically well designed and is user-friendly. Many of the materials including polymers, coatings, steels and organic materials can be used in this equipments to undergo erosive wear tests. The equipment assembly comprises of a compressor, a particle feeder, air particle mixing chamber, nozzle sand hopper, conveyor belt and sample holder. The compressor is responsible for compressing the air at a specific pressure. The erodent is fed by the conveyor belt at a constant rate. This erodent is mixed with the air and the nozzle arrangement speeds up the mixture of air and erodent to erode the target material. The nozzle is

4mm in diameter made up of Tungsten Carbide. The specimen can be place at various angles using a sample holder which is adjustable in nature.

Fig 4.1 Details of erosion test rig. (1) Sand Hopper, (2) Conveyor belt system, (3) Pressure transducer, (4) Air-particle mixing chamber, (5) Nozzle, (6) X-Y and h axes assembly, (7) sample holder.

To measure the velocity of the erodent particle, the test apparatus is fitted with rotating double disc. Table-4.1 shows velocities obtained for different pressures using the rotating double disc method. Table-4.2 depicts the conditions in which the test has been carried out.

Table-4.1 Particle velocity under different air pressures

Sl. No.	Air Pressure (Bar)	Particle velocity (m/s)
1	1	48
2	2	70
3	3	82

Table-4.2 Experimental conditions for the test

Test parameters	
Erodent:	Silica sand
Erodent size (μ m):	(200±50)
Erodent shape:	Angular
Hardness of silica particles (HV):	(1420±50)
Impingement angle (α^0):	30º, 45º, 60º and 90º
Impact velocity (m/s):	48, 70 and 82
Erodent feed rate (g/min):	(2.1±0.40)
Test temperature:	(27 ^{0}C)
Nozzle to sample distance (mm):	~10

4.4.3 Experimental Procedure

Steps taken to conduct the solid erosion test were as follows-

1. Clean the test apparatus and make sure that all the switches, valves, knobs are closed .
2. Connect the test apparatus to 230 V supply and switch on the apparatus.
3. Start the compressor.
4. Wipe the sample with acetone and weigh it before placing it on the sample holder. Then place all the 16 specimens on the sample holder at the desired angle.
5. Set the timer for which the test would run.
6. Set the required speed for the conveyor belt.
7. Adjust the nozzle with the help of adjusting nut.
8. Press the start button after closing all the doors of the apparatus.
9. Remove, clean and weigh the specimen after the test is completed.
10. Note the difference in weights (Δw).

4.5 Sample Calculation

The calculation of the erosion rate was done by the following equation-

$$E_r = \frac{W_s}{W_e}$$

where,

Δw - weight loss of the sample (initial weight-final weight).

W_e – Weight of erodent (g)

W_e = testing time × particle feed rate.

4.6 Experimental Results

The experiments were conducted for time period of 10 minutes for every sample. The stand-off distance between the nozzle and the specimen to be tested was held close to 1 cm. The mass flow rate of the erodent was taken in the range of (2.1±0.40) g/min. The specimens were tested for air pressures 1 bar, 2 bar and 3 bar corresponding to particle velocities of 48 m/s, 70 m/s and 82 m/s respectively.

Based on the various test parameters, experiments were conducted and the results obtained are shown in Table 4.3 to Table 4.6.

Table 4.3 - Weight loss and Erosion rate of 5% Pomegranate peel powder reinforced epoxy composites with respect to impingement angle

Velocity (m/s)	Impact Angle (°)	Weight loss 'Δw' (g)	Erosion Rate (g/g)
48	30^0	0.005	0.00029
	45^0	0.002	0.00074
	60^0	0.003	0.00044
	90^0	0.004	0.00059
70	30^0	0.005	0.00079
	45^0	0.01	0.00147
	60^0	0.007	0.00103
	90^0	0.003	0.00047
82	30^0	0.009	0.00133
	45^0	0.043	0.0019
	60^0	0.031	0.00137
	90^0	0.013	0.00192

Table 4.4 -Weight loss and Erosion rate of 10% Pomegranate peel powder reinforced epoxy composites with respect to impingement angle

Velocity (m/s)	Impact Angle (°)	Weight loss 'Δw' (g)	Erosion Rate (g/g)
48	30^0	0.002	0.00029
	45^0	0.002	0.00029
	60^0	0.003	0.00044
	90^0	0.003	0.00044
70	30^0	0.004	0.00063
	45^0	0.005	0.00079
	60^0	0.006	0.00094
	90^0	0.003	0.00047
82	30^0	0.01	0.00147
	45^0	0.047	0.00208
	60^0	0.037	0.00164
	90^0	0.011	0.00162

Table 4.5- Weight loss and Erosion rate of 15% Pomegranate peel powder reinforced epoxy composites with respect to impingement angle

Velocity (m/s)	Impact Angle (°)	Weight loss ‘Δw’ (g)	Erosion Rate (g/g)
48	30^0	0.007	0.00044
	45^0	0.003	0.00103
	60^0	0.003	0.00044
	90^0	0.003	0.00044
70	30^0	0.008	0.00126
	45^0	0.008	0.00118
	60^0	0.006	0.00088
	90^0	0.004	0.00063
82	30^0	0.012	0.00177
	45^0	0.045	0.00199
	60^0	0.036	0.00159
	90^0	0.014	0.00206

Table 4.6- Weight loss and Erosion rate of 20% Pomegranate peel powder reinforced epoxy composites with respect to impingement angle

Velocity (m/s)	Impact Angle (°)	Weight loss 'Δw' (g)	Erosion Rate (g/g)
48	30^0	0.008	0.00118
	45^0	0.01	0.00147
	60^0	0.003	0.00044
	90^0	0.002	0.00029
70	30^0	0.008	0.00126
	45^0	0.008	0.00126
	60^0	0.009	0.00142
	90^0	0.004	0.00063
82	30^0	0.016	0.00236
	45^0	0.049	0.00217
	60^0	0.033	0.00146
	90^0	0.015	0.00221

CHAPTER 5

RESULTS AND DISCUSSIONS

CHAPTER 5

RESULTS AND DISCUSSIONS

Based on the experimental results shown in the above tables Table 4.3 to Table 4.6, various graphs were plotted as shown in the figures Fig 5.1, Fig 5.2 and Fig 5.3. The impingement angle is one of the most important factors that is needed to study the erosive wear behavior of composites. The ductile nature of the composite is portrayed by maximum erosion at low impingement angles i.e. 15°<α<30°.Also, if the maximum erosion rate occurs in the range 60°<α<90°, the material is brittle in nature. As it is known earlier, reinforced composites can also exhibit semi ductile nature with maximum erosion rate at intermediate impingement angles; typically 30°< α <60°. In the present case, maximum erosion occurs at an impingement angle of 30°< α <60° which indicates that these composites are neither purely ductile in nature nor purely brittle in nature but are semi-ductile in nature. It is also seen from all the graphs that the erosion rate of material having 5% reinforced filler is less than that of 20% particulate filler. This shows that the erosion rate increases when filler content in the composite is increased.

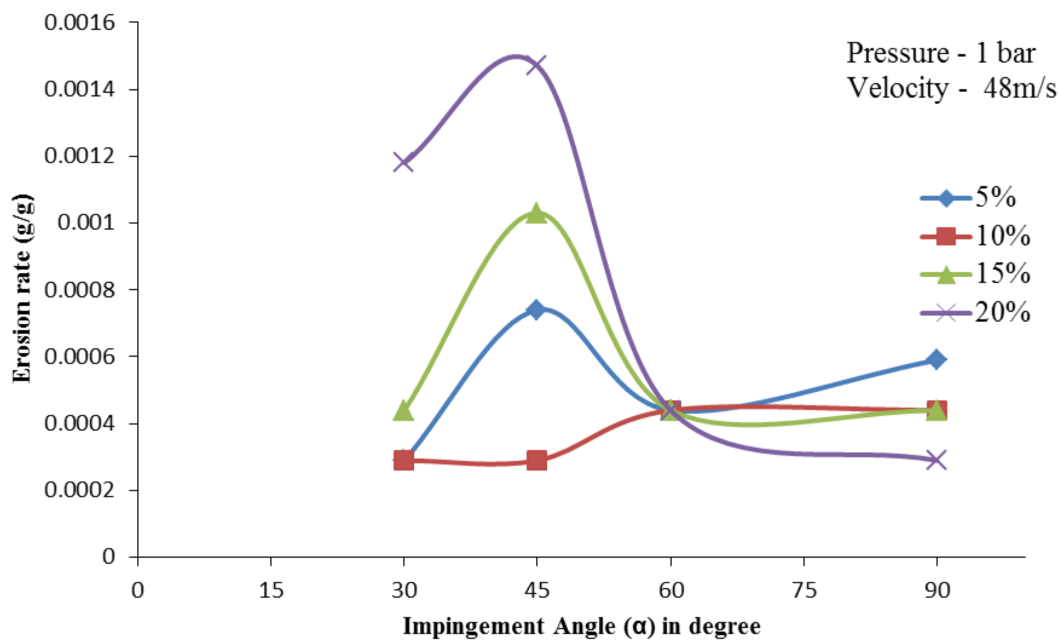

Fig 5.1 Variation of erosion rate with impact angle of various weight percentages (5%, 10%, 15% and 20%) of Pomegranate peel powder filled epoxy composite at impact velocity of 48m/s.

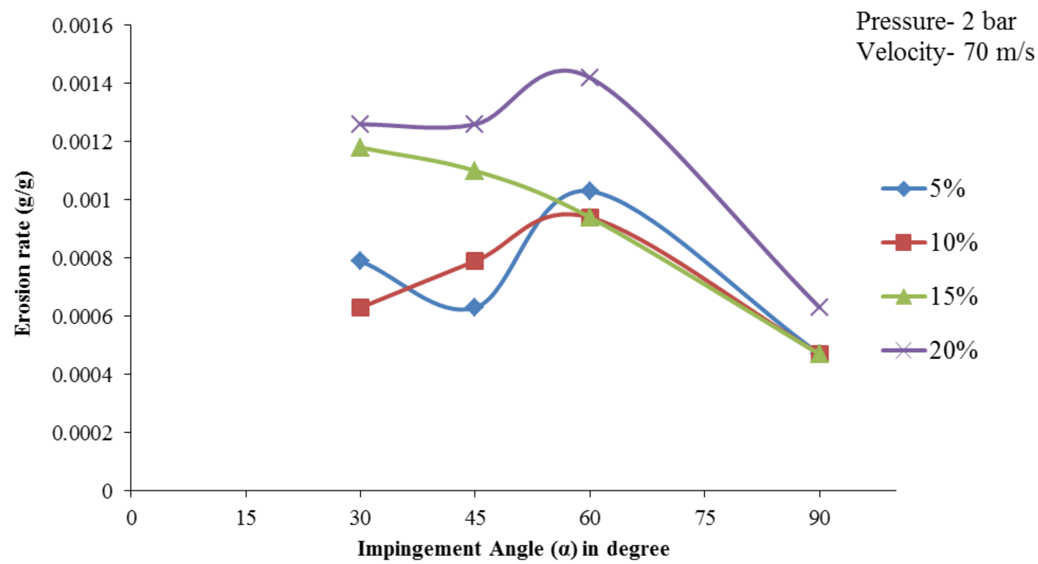

Fig 5.2 Variation of erosion rate with impact angle of various weight percentages (5%, 10%, 15% and 20%) of Pomegranate peel powder filled epoxy composite at impact velocity of 70m/s.

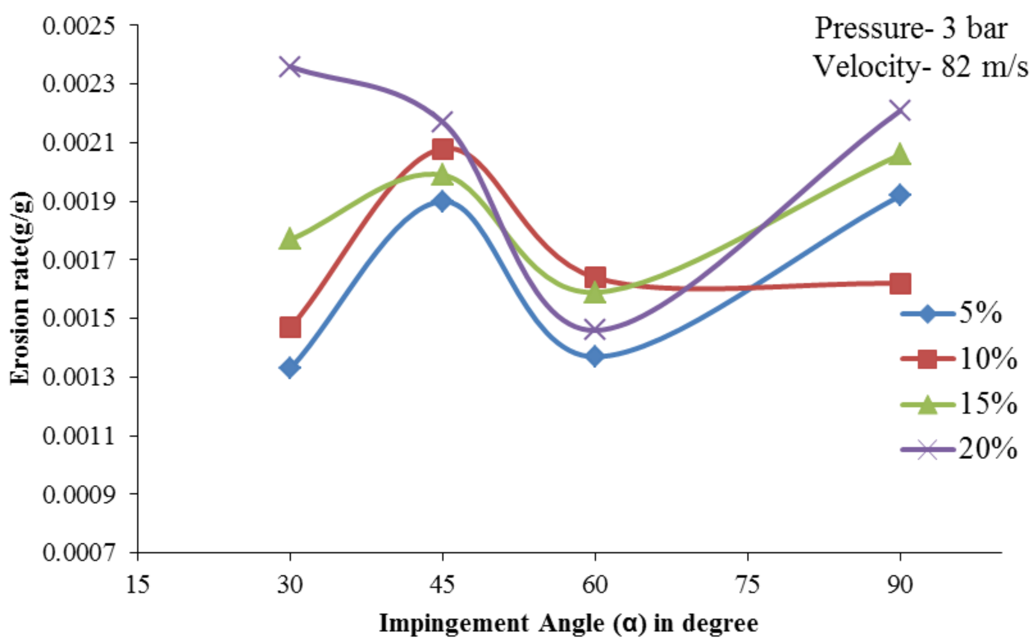

Fig 5.3 Variation of erosion rate with impact angle of various weight percentages (5%, 10%,15% and 20%) of Pomegranate peel powder filled epoxy composite at impact velocity of 82m/s.

CHAPTER 6

CONCLUSIONS AND SCOPE FOR FUTURE WORK

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6.1 Conclusions

Based on the study of the erosive wear behavior of Pomegranate peel powder reinforced epoxy composite at various impact velocities and impingement angles for different filler weight fraction with erodent as silica sand, the following conclusions are drawn-

- Hand Lay-Up technique was adopted to fabricate the composite material successfully.
- The composite prepared with Pomegranate peel powder shows maximum erosion rate at an impingement angle between 30° and 60° which depicts semi-ductile behaviour of the material.
- It is observed from the graphs that the erosion rate of composite having 20% filler weight fraction is greater than the erosion rate of composite having 5% filler weight fraction.This depicts that the erosion rate increases when filler content in the composite is increased.
- Weight percentage of particulate filler in the composites and velocity of impact of the erodent plays an important role in determining the erosion wear rate of the composites and thus its nature.
- Increase in the weight fraction of filler in the composite also leads to void formation which fluctuates the composites behaviour. Hence, balanced composite results in less wear rate in comparison to unbalanced composites.
- When weight fraction of the filler is increased in the composite, formation of voids and weak interface takes place in the composites which changes the composite's behaviour.

6.2 Scope for future work

This work leaves a wide scope for future researchers to investigate many other aspects of the Pomegranate peel reinforced epoxy composites.

- The work on this composite can be extended to abrasive wear tests on pin-on disc machine or three body abrasive wear test machine.

- The current study was limited to tribological test only. It can be further extended to Mechanical behavior tests.

- The present study involved only Pomegranate peel powders as reinforcement. The work can involve usage of different reinforcement materials like metals, natural and synthetic fiber along with the Pomegranate peel powder for erosive wear tests.

- Higher weight percentages of filler can also be taken for further erosion test for better results.

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